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Diurnal vertical migrations of cod and rock grenadier in the northwest Atlantic

P. I. Savvatimskii

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DIURNAL VERTICAL MIGRATIONS OF COD AND ROCK GRENADIER IN THE NORTHWEST ATLANTIC

By P.I. Savvatimskii (Polar Scientific Research Institute of Marine Fisheries and Oceanography (PINRO)).

The rock grenadier is a deep-water fish that feeds mainly on plankton, /67* small fishes and shrimp. The diurnal migrations of plankton, which embrace layers to depths of 800-1000 m or more are well known (Vinogradov, 1968). There exist maxima in the abundance and biomass of plankton at depths of 2000-3000 m, where the amount of plankton exceeds the average amounts by several times. This creates a stable forage base for deep-water fishes, and in particular, for the rock grenadier.

The type and intensity of diurnal migrations of fishes depend on the /68 nature and peculiarities of their feeding (Zusser, 1967; Konstantinov, 1968; Konstantinov, Turuk, 1972).

As a rule fish that feed on bottom food rise into the water mass in the day. Planktophages ascend in the evening after the plankton and descend to the bottom in the morning, so that day catches with a bottom trawl are much greater than night ones.

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The rock grenadier, like the cod and haddock (Konstantinov, Turuk, 1968), is characterized by two types of diurnal vertical migrations. If planktonic crustanceans predominate in its feeding, then it ascends into the water mass by night; if benthic shrimps - then by day (Savvatimskii, 1969, 1970). In the Northern Labrador region, from November 22nd until December 6th, 1971, rock grenadier catches in bottom trawls by the "Persei-III" scientific-exploratory vessel by day were much greater (up to 10 centners per hour of trawling), than by night and in the morning (4 centners) (Fig. 1). The rock grenadier fed mainly on small planktonic crustaceans and anchovies, as well as shrimps. Typical bottom food was not found in stomachs when they were opened up (Fig. 2). By day, the rock grenadier fed mainly on shrimps, by night on anchovies and small plankton. In fish caught in the daytime (from 12:00 to 16:00), shrimps were found in the stomachs of 28% fish opened; they were present in only 11% of fishes caught in the morning (from 4:00 to 8:00). Planktonic crustaceans and anchovies were more often found in the stomachs of fishes in the morning. The rock grenadier thus made at that time diurnal vertical migrations of the first type - based on the the classification proposed by K.G. Konstantin and T.N. Turuk (1968, 1972).

The mouth parts of the rock grenadier are adapted for feeding on small /69 animals. Such a large and relatively hard object as the shrimp, which has a shell, was more often found in the stomachs of longer fishes, while planktonic crustaceans predominated in the feeding of small fishes (Table 1).

The diurnal vertical migrations were more pronounced in small fish than in larger ones, and it is therefore larger grenadier that get into bottom trawls by night (Fig. 3, A). Differences in the size make-up of bottom catches by day and by night in connection with feeding peculiarities have also been noted

/68

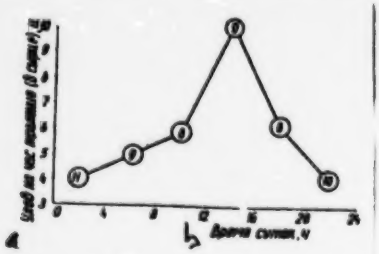

Fig. 1. Average catches of rock grenadier in the Northern Labrador region in 1971 depending on the time of day (number of catches indicated in the circles).

a - catches per hour of trawling, whole weight, centners.
b - time of day, h.

Fig. 2. Make-up of food of rock grenadier in Northern Labrador region in 1971.

a - shrimp; b - Themisto (pelagic amphipod); c - digested fish; d - anchovies; e - small pelagic crustaceans; f - Calanus (copepod); g - krill; h - ctenophores; i - squid.

TABLE 1

Frequency of occurrence of different food components in the stomachs of small and large rock grenadier in Northern Labrador from November 22nd until December 6th, 1971, as % of the total number of stomachs opened, including empty ones. /69

1	2 Объекты питания					
Длина рыб, см	мелкий планктон 3	темисто 4	анчоус 5	переваренная рыба 6	креветка 7	количество рыб 8
До 69 9	46,0	I8,0	5,I	I9,7	I3,I	533
70 и более 10	38,I	I9,9	II,2	20,3	2I,2	439

1 - length of fish, cm; 2 - food objects; 3 - small plankton; 4 - Themisto; 5 - anchovy; 6 - digested fish; 7 - shrimp; 8 - amount of fish.; 9 - up to 69; 10 - 70 or more.

for another planktophage - the Bering Sea walleye pollock (Serobaba, 1969).

Catches of the rock grenadier by the "Artemida" Scientific Research Vessel in the region of Notre Dame Bay in November 1973 by day were also greater than by night (Table 2).

TABLE 2

Average catch (tonnes) of grenadier and halibut per hour of trawling in the region of Notre Dame Bay November 7-13, 1973.

Время суток, ч 1	Макрурус 2	Палтус 3	Количество уловов 4
08-20	I,68	0,I4	II
20-08	I,29	0,02	7

1 - time of day, h; 2 - grenadier; 3 - halibut; 4 - number of catches.

It was mainly small fishes that migrated by night into the water mass. There were more large fish in night catches with a bottom trawl than in day ones (see Fig. 3, B). The frequency of occurrence of amphipods in the stomachs of opened fish, caught at night was higher, and that of shrimps - lower (Fig. 4). The shrimp is more accessible to large fish and are used by them to a greater extent than by smaller ones, which prefer plankton (Table 3).

These data may explain the predominant migrations into the water /71
mass of small fishes. S.G. Zusser (1971) writes that in the migrations of plankton-eating fishes into the water mass by night, a two-layered vertical distribution is often observed: fry and small fishes are found in the upper layer, and larger fishes in the lower layer. This confirms our hypothesis that diurnal vertical migrations are more pronounced in the small rock grenadier.

/70

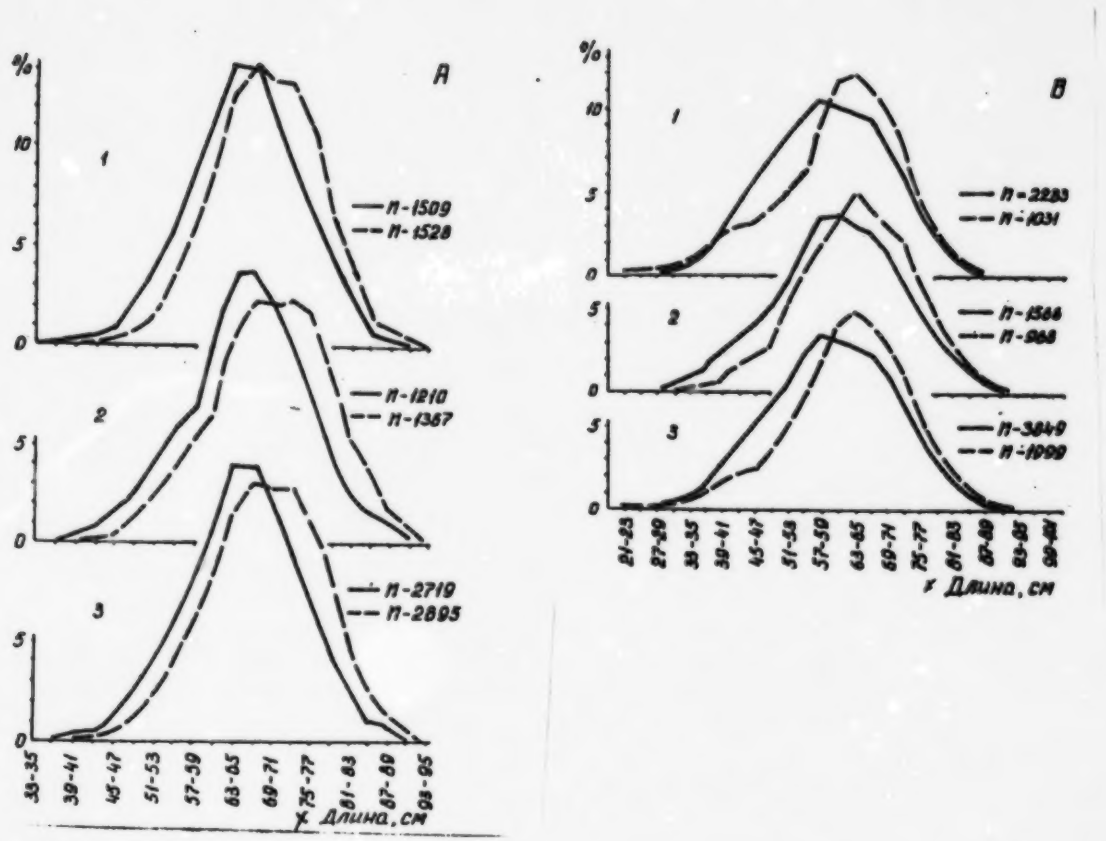

Fig. 3. Size make-up of bottom catches of rock grenadier in the Northern Labrador region, November 22nd, - December 6th, 1971 (A) and in the region of Notre Dame Bay in November, 1973 (B) from 8:00 to 20:00 (solid line) and at night - from 20:00 to 8:00 (dashed line):

1 - males; 2 - females; 3 - males and females (smoothed-out size series). The curves are shown in smoothed-out form in Fig. 3, 4, and 6. Smoothing out of series was done by the formula $B = (a + 2b + c)/4$ where a, b, c are the preceding term, mean and subsequent term of the series, B - is the calculated series. x - length, cm

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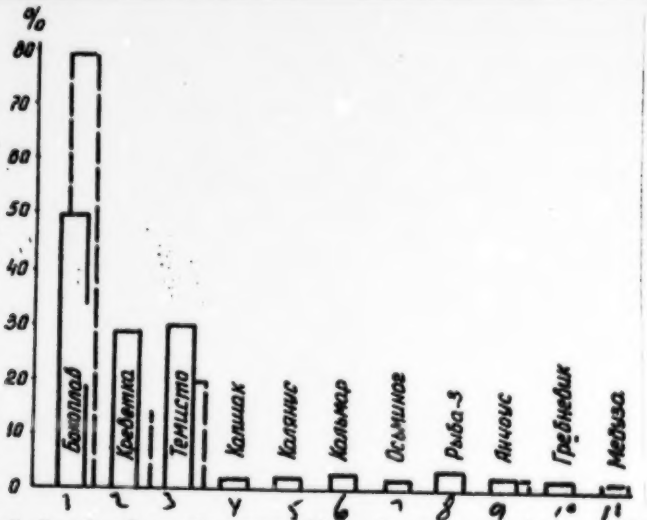

Fig. 4. Make-up of food of rock grenadier in the region of Notre Dame Bay in November 1973 by day (solid line) and night (dashed line).

1 - amphipods; 2 - shrimp; 3 - Themisto; 4 - krill; 5 - Calanus; 6 - squid; 7 - octopus; 8 - fish-3; 9 - anchovy; 10 - ctenophore; 11 - medusa.

Table 4 shows clear differences in catch parameters in the day and at night /71
in both regions where studies were done. By day, the average length of fishes, the mode and relative number of females in catches were smaller than at night. Differences in the sexual make-up of catches are explained by the fact that /72
the migration is more pronounced in males since they are smaller than females.

TABLE 3

Frequency of occurrence of different food components in small and large rock grenadier in the region of Notre-Dame Bay, November 7-13th, 1973, % of total number of stomachs opened.

1 Объект питания	2 Рыбы длиной, см 23-63	64-95	1 Объект питания	2 Рыбы длиной, см 23-63	64-95
Бокоплав 3	62,I	30,I	Медуза 9	-	0,8
Креветка 4	I0,6	24,4	Осьминог 10	-	I,6
Темисто 5	I2,9	26,0	Кальмар 11	-	I,6
Капшак 6	I,5	-	Анчоус 12	-	2,4
Калянус 7	-	I,6	Рыба 13	0,8	2,4
Гребневик 8	0,8	-			

1 - food object; 2- fish of length, cm; 3 - amphipod; 4 - shrimp; 5 - Themisto; 6 - krill; 7 - Calanus; 8 - ctenophore; 9 - medusa; 10 - octopus; 11 - squid; 12 - anchovy; 13 - fish. Note. No shrimps less than 50 cm long were found in fish stomachs.

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TABLE 4

Characteristics of rock grenadier bottom catches

Характеристика уловов 1	Пол 2	Северный Лабрадор, (ноябрь-декабрь, 1971 г.) 3		Залив Нотр-Дам, (ноябрь, 1973 г.) 4	
		08-20 ч	20-08 ч	08-20 ч	20-08 ч
5 Мода, см	Самцы 9	63-65	66-68	57-59	63-65
6 Средняя длина, см		65,47	68,76	59,47	61,84
7 Количество в улове, %		55,5	52,8	59,3	51,6
8 Количество рыб		1509	1528	2283	1031
5 Мода, см	Самки 10	63-65	66-68	60-62	63-65
6 Средняя длина, см		66,01	69,67	61,42	64,66
7 Количество в улове, %		44,5	47,2	40,7	48,4
8 Количество рыб		1210	1367	1566	968
5 Мода, см	Самцы и самки 11	63-65	66-68	57-59	63-65
6 Средняя длина, см		65,71	69,19	60,25	63,22
7 Количество в улове, %		100	100	100	100
8 Количество рыб		2719	2895	3849	1999

1 - characteristics of catches; 2 - sex; 3 - Northern Labrador (November-December, 1971); 4 - Notre Dame Bay (November, 1973); 5 - mode, cm; 6 - average length, cm; 7 - amount in catch, %; 8 - number of fish; 9 - males; 10-females; 11 - males and females.

A.A. Baral (1978) notes that in the Northern Labardor region, the rock /72
grenadier rises into the water mass by day and returns to the bottom at night. The author unfortunately does not indicate when the observations were made, although it is known that the nature and rate of the vertical migrations of fishes can vary at different times of the year (Zusser, 1971). In addition, the author does not relate the diurnal migrations to the nature of the feeding of the fishes that governed the type of migration.

Diurnal migrations are typical of the rock grenadier not only of the Northwestern, but also of the Northeastern Atlantic. Judging by the maximal catches of this fish at night in December 1976 on the George Bligh* and Hutton* banks, the grenadier was making migrations of the second type. Shrimps and squids made up the bulk of its food; small stones and silt were found in the stomachs of opened fish, indicating that the grenadier was feeding near the bottom.

All the above relates to bottom catching. When the grenadier makes diurnal vertical migrations of the first type, that is, when it rises into the water mass at night, we might expect that catches with a midwater trawl would increase at night and decrease in the day. Thus, in the second half of August, 1979 in the region of Central Labrador, catches of commercial large freezer trawlers with midwater trawls were between 10 and 25 tonnes at night /73 and in the morning, and from 8 to 10 tonnes by day. The grenadier accumulations occupied a large layer of the water mass. The trawling levels were 600-900 m at a sea depth of 900-1400 m.

The cod, in feeding on washer and anchovy, also makes diurnal vertical migrations of the first type. On an exploratory-research voyage of the "Persei-III" in the Southern Labrador region (eastern slope of the Hamilton banks) on November 7-11, 1971, bottom trawl cod catches differed sharply by day (from 8:00 to 20:00) and by night (from 20:00 to 8:00). The average cod catch by day was 4.93, and by night 1.44 centners. The cod was fattening up intensively on washer. The washer was found in the stomachs of 76% of all fish opened (440 specimens). The stomach fulness was 2.6 on a five-point scale. The trawling was done at depths of 200-260 m.

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*Spelling approximate. - Transl.

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TABLE 5

Average cod catches (in centers of raw fish per h of trawling) with a bottom trawl in the day and at night with trawling with the current (in a southern direction) and against the current (in a northern direction) in the Southern Labrador region from December 8th to 31st, 1971.

Время суток, ч (1)	Средний улов, ц (2)	Средний улов, ц (3)	
		по течению (4)	против течения (5)
08-20	4,4 / 61	5,4 / 30	3,4 / 31
20-08	3,1 / 59	2,9 / 35	3,5 / 24
За сутки (6)	3,8 / 120	4,1 / 65	3,4 / 55

1 - time of day, h; 2 - average catch, centners; 3 - average catch, centers; 4 - with the current; 5 - against the current; 6 - in a day.

Note. In numerator - average catches; in denominator - number of trawls.

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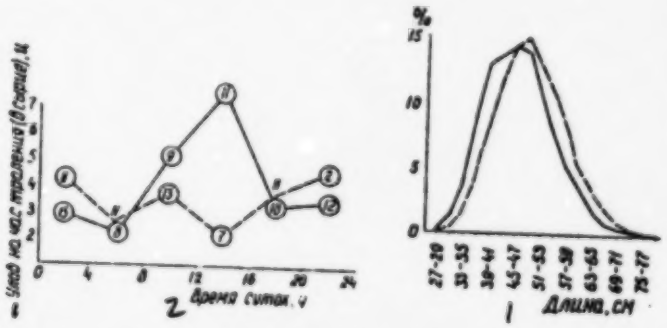

Fig. 5. Fluctuations in cod catches depending on time of day in the Southern Labrador region on December 8-31st, 1971 in trawling with the current (solid line) and against the current (dashed line); the numbers in the circles indicate the number of catches.
1 -.catches per hour of trawling (in raw fish), centners; 2 - time of day, h.

Fig. 6. Size make-up of bottom catches of cod in the Southern Labrador region on December 8-31st, 1981 by day - 08:00-20:00 h (solid line) and by night 20:00-08:00 (dashed line) in trawling with the current (30,429 fish spec., smoothed out series).
1 - length, cm.

Echo sounders showed that by day the washer was situated in the bottom /74
layer and at night in the water mass, 120 m from the bottom. The cod, in feeding on the washer, made intensive vertical migrations, ascending after it into the middle water layers.

In the same region (eastern and southeastern slopes of the Hamilton banks), 120 hauls of a bottom trawl were done between December 8th and 31st, 1971 at depths of 260-300 m. Long work at the cod stock in December revealed a clear periodicity in trawl catches in the day and night times and variations in the size make-up of the cod caught. Anchovies, amphipods and shrimp made up the bulk of the cod food. The average stomach fulness was 0.91. The cod made diurnal vertical migrations by night into the water mass, which is indicated by the echo sounder readings and the flucuations in catches during the course of the day (Table 5).

The trawling courses were situated in southern (along the Labrador Current) and northern (against the current) directions. The catches varied, and their diurnal periodicity showed up only in trawling with the current (Fig. 5). The average catches per hour of trawling were above 7 centners between 12:00 and 16:00 and decreased at night to 3-4 centners. Some reduction in catches from 4:00 to 8:00 is explained by the greater activity of the cod in search of food in the morning (in the twilight hours), which is characteristic of many fishes (Konstantinov, 1981). The cod often rises over the bottom at this time, /75
so that bottom trawl catches decline.

Trawling with the current showed the most distinct differences in the size make-up of catches: the cod was smaller by day than at night (Fig. 6), which indicates a predominant migration of small fishes into the water mass. In trawling against the current, the size make-up of the day and night catches

was practically identical and the catches themselves did not vary in magnitude. The intensity of feeding of the cod during the course of the day was almost unvaried. The average stomach fulness of the fishes by day was 1.04, by night 0.93. By day, the cod fed mainly on amphipods, Themisto and shrimp situated near the bottom, and by night on anchovy. The anchovy was found in the stomachs of 20% of the fishes caught by night, and in 14% of those caught by day.

Not only catches, but also the size make-up of the cod varied in trawling with the current and against the current, regardless of the time of day, so that in studying the diurnal vertical migrations of the fish, the direction of trawling with respect to the current must also be taken into account.

Study of the behavior of the cod and grenadier, particularly their /76 diurnal vertical migrations, is of definite interest in connection with the efficient distribution of fishing time. It is advisable to make a large number of bottom trawls at that time when the fish are near the bottom, and to put off other operations, such as repair or replacement of fishing gear, to a time of day that is less productive for fishing (Konstantinov, 1981). In addition, as some investigators have noted (Zusser, 1971; Baral, 1978), catching methods can be changed depending on the distribution of the fishes during the course of the day (for example, bottom and midwater catching can be alternated). It must also be kept in mind that the variation in the size and sexual make-up of catches during the course of the day is reflected in the assortment and value of the fish products that can be produced.

Conclusion

The rock grenadier and the cod are characterized by diurnal vertical migrations of two types, as a result of which day and nighttime catches by bottom trawl can differ by more than a factor of two. This must be taken into account in the distribution of fishing time over the course of the day and

and in the selection of catching methods (bottom and midwater) for an effective fishery.

The type and intensity of fish migrations are determined by the nature of feeding. The rock grenadier, as a rule, makes nocturnal migrations into the water mass after food - plankton and anchovy, as a result of which daytime catches by bottom trawl will be greater than nighttime ones. If bottom forms of shrimps predominate in the food of the grenadier, then it makes vertical migrations of the second type, so that catches increase at night and decrease in the day.

The size and sexual make-up of bottom catches of cod and rock grenadier varies depending on vertical migrations, which is reflected in the assortment and value of fish products produced. The small grenadier, feeding on plankton, and the small cod, that feeds on anchovy, make more intensive migrations than the larger fish, which is in fact the cause of differences in the size make-up of day and nighttime catches. The size make-up of cod catches also varied depending on the direction of trawling with respect to the current, which must be taken /77 into account int studying the diurnal vertical migrations of the fish.

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